

Application for Letters Patent of

the UNITED STATES OF AMERICA by –

William A. White, III  
97 Sunset Road  
Carlisle, MA 01824

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THE UNITED STATES OF AMERICA

For:

SYSTEM AND METHOD FOR OPTIMAL SETTING OF  
MESSAGE ACCEPTANCE FILTERS

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## SYSTEM AND METHOD FOR OPTIMAL SETTING OF MESSAGE ACCEPTANCE FILTERS

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### TECHNICAL FIELD

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The present invention relates generally to the field of network communication. More specifically, the present invention relates to systems that utilize mask/value filters to specify acceptance parameters wherein messages are accepted based on an identifying number contained in the message.

### BACKGROUND OF THE INVENTION

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Network communication exists in various forms. One specific form is to utilize message accept/reject filters. In such a system, messages are accepted or rejected based on an identifying number contained in the message that matches (accept) or does not match (reject) a mask or value filter.

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Devices connected within a communication network utilizing message acceptance filters will facilitate communication among each other by including a message identifier within each transmitted message. From the device perspective, the message identifier determines whether or not an incoming message is addressed to it. If so, the device will accept/filter the message and process the data. If not, the message will be rejected.

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Filtering of the message can generally be accomplished in a variety of ways. In one technique, the module can either refuse the unwanted messages by implementing hardware filters. In another technique, all the wanted messages are initially accepted and then the unwanted messages are rejected via a software filtering process.

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Software filtering has at least two drawbacks. One of which is a possible overload of the input buffers in the device. Another software shortcoming is the supplementary CPU activity required in such filtering. Hardware filters can also consume a great amount of time and CPU capacity.

Generally, message identifiers are chosen such that the filter can be chosen simply. However in some cases, e.g., ST7 microprocessors, the message identifiers and

5 the filters have been prescribed and are not capable of being modified. In such a  
inflexible network, it is desirable to create a system capable of accepting all desired  
messages and rejecting the optimal amount of unwanted messages.

This invention is designed to solve these and other problems.

## 10 SUMMARY OF THE INVENTION

The present invention is directed to a method for improving network  
communication utilizing acceptance filters. More specifically, one embodiment of the  
present invention provides a method for optimizing communication in a network.  
Communication on the network involves wanted and unwanted messages wherein a set of  
15 filters are configured to accept all wanted network messages and minimize the acceptance  
of unwanted messages in accordance with a selection criteria. The method comprises  
configuring a first filter to receive all wanted messages. The first filter includes a defined  
bit and an undefined bit. Each defined bit is either in a first state or in a second state. A  
second filter is set equal to the first filter. The first filter and the second filter compose a  
20 first set of filters. Potential configurations of the first set of filters are determined  
wherein each potential configuration of the first set of filters is capable of accepting all  
wanted network messages. Each potential configuration of the first set of filters is  
optimized to reduce acceptance of unwanted messages while continuing to ensure  
acceptance of all wanted messages.

25 A further aspect of the present invention includes selecting an optimum  
configuration of the first set of filters in response to a selection criteria. The optimum  
configuration of the first set of filters is selected from the potential configurations of the  
first set of filters.

30 An object of the present invention is to provide a method of improving the  
efficiency of hardware filters and reduce the accompanying complexity to set them.

Another object of the present invention is to determine the optimal configuration  
of a message acceptance filter for improving network communication.

Yet another object of the present invention is to provide a method of facilitating  
communication among operably connected devices on a network having prescribed and  
35 fixed message identifiers.

5 Other features and advantages of the invention, which are believed to be novel and nonobvious, will be apparent from the following specification taken in conjunction with the accompanying drawings in which there is shown a preferred embodiment of the invention. Reference is made to the claims for interpreting the full scope of the invention which is not necessarily represented by such embodiment.

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**BRIEF DESCRIPTION OF THE DRAWINGS**

FIG. 1 is a block diagram of a communication network;

FIG. 2 is a block diagram of the internal structure of a device connected to the communication network; and,

15 FIG. 3 is a block diagram of the filter structure of one embodiment of the present invention.

**DETAILED DESCRIPTION**

20 Although this invention is susceptible to embodiments of many different forms, a preferred embodiment will be described and illustrated in detail herein. The present disclosure exemplifies the principles of the invention and is not to be considered a limit to the broader aspects of the invention to the particular embodiment as described.

Referring to FIGS. 1 and 2, devices 12 on a network 10 communicate with each other by sending messages 14 having a message identifier 16 over a communication bus 18. From the perspective of each device 12, the message identifier 16 determines whether or not an incoming message is addressed to the device. If so, the device 12 will filter/accept the message and process the accompanying data. If not, the message will not be accepted.

25 The acceptance of the message 14 is accomplished through filtering. One filtering technique utilizes hardware filters to reject an unwanted message. Another filtering technique accepts all the messages and implements a software filter to later reject the unwanted message. FIG. 3 depicts one embodiment of a filter structure. Messages 14 are received at the filters 20 from the communication bus 18 and are processed to the CPU, registers, etc.

Both software and hardware filters have drawbacks. For software, the input buffers of the devices can be overloaded due to the acceptance of all the messages 14. Additionally, CPU activity may need to be supplemented. For hardware, the setting of the hardware filters can consume a great deal of time and CPU resources. The present invention proposes an embodiment comprised of both hardware and software filters.

More specifically, a system and method are described to set the hardware filters in an effective manner. Although the final result may be less than optimal, the results, both in the savings of processing and time, are significantly better than the results of past techniques.

One embodiment of the present invention provides a method for optimizing communication in a network. Communication on the network involves wanted and unwanted messages wherein a set of filters are configured to accept all wanted network messages and minimize the acceptance of unwanted messages in accordance with a selection criteria. The method comprises configuring a first filter to receive all wanted messages. The first filter includes a defined bit and an undefined bit. Each defined bit is either in a first state or in a second state. A second filter is set equal to the first filter. The first filter and the second filter compose a first set of filters. Potential configurations of the first set of filters are determined wherein each potential configuration of the first set of filters is capable of accepting all wanted network messages. Each potential configuration of the first set of filters is optimized to reduce acceptance of unwanted messages while continuing to ensure acceptance of all wanted messages.

Network messages include an identifier,  $m$ , having a size of  $n$  bits, e.g.,  $m = m_{n-1}, m_{n-2}, \dots, m_1, m_0$ .  $M_w$  represents a set of wanted messages in the bus 18 and  $M_p$  represents a set of possible messages on the bus.  $F$  is a set of filters, i.e.,  $\{F_1, F_2, F_3, \dots, F_i\}$  wherein  $F_i$  is the  $i$ th filter, e.g.,  $F_i = f_{n-1}, f_{n-1} \dots f_1, f_0$ ; and each filter has three possible settings: match, no match, and don't care, i.e.,  $f_j = \{1, 0, X\}$ .

For a filter  $F_i$ , a message  $m$  will be accepted if and only if each bit,  $m_j, j = 0, 1, \dots, n-1$ ; is equal to  $f_j$ , unless  $f_j = X$ , the don't care state. The equation below is shown to relate the concept that a filter be configured to accept at least all the wanted messages. That is, for ( $j = 0, j < n, j++$ )

{            if  $((f_j == X) \text{ or } (f_j == m_j))$             {do not reject and continue}

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5      else
        {reject and stop}
    }
}

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Optimization of a single filter is expressed below in equation format. For each bit position of the filter,  $j$ , if the bits,  $m_j$ , of all the wanted messages,  $M_w$ , are identical, then set the corresponding filter components,  $f_j$ , to these values; else, set the value to an X, e.g., “don’t care.” That is, for ( $j = 0, j < n, j++$ )

In an optimal setting for an P-filter set, i.e.,  $F = \{F_1, F_2, \dots, F_P\}$ , the solution comprises testing all the possible configurations of the filters and then choosing the one that incorporates the desired constraint.

$M_w$  represents a set of wanted messages, i.e.,  $M_w = \{m_1, m_2, m_3, m_4, m_5, m_6\}$ , wherein  $m_1 = 0011\ 0100\ 1001$ ;  $m_2 = 1010\ 0010\ 1010$ ;  $m_3 = 1110\ 0001\ 1100$ ;  $m_4 = 0101\ 0110\ 1000$ ;  $m_5 = 1000\ 1001\ 1000$ ; and  $m_6 = 0011\ 0101\ 1010$ .

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5 that are allowed to pass through  $F_1$ , it is still significantly less than allowing all messages to pass through, i.e.  $2^{12}$ .

Utilizing the same wanted messages for the single filter example shown above, a further example is now provided for a two filter set. Preferably, the first filter,  $F_1$ , is initialized and set equal to a wanted message.  $F_1$  is then optimized wherein its bits are set to a value that will allow  $F_1$  to accept every wanted message. In this example,  $F_1 =$   
 10 XXXX XXXX 1XXX. A second filter,  $F_2$ , is set equal to  $F_1$ , i.e.,  $F_1 = F_2 =$  XXXX XXXX 1XXX. The filters are then configured to determine potential configurations of the first filter set,  $F_1$  and  $F_2$ . The potential configurations for the first filter set are determined by individually replacing each X with a 0 for  $F_1$ , and a 1 for each  
 15 corresponding X of  $F_2$ :

	1st case:	$\{F_1 = 0XXX XXXX 1XXX, F_2 = 1XXX XXXX 1XXX\},$
	2nd case:	$\{F_1 = X0XX XXXX 1XXX, F_2 = X1XX XXXX 1XXX\},$
	3rd case:	$\{F_1 = XX0X XXXX 1XXX, F_2 = XX1X XXXX 1XXX\},$
	4th case:	$\{F_1 = XXX0 XXXX 1XXX, F_2 = XXX1 XXXX 1XXX\},$
20	5th case:	$\{F_1 = XXXX 0XXX 1XXX, F_2 = XXXX 1XXX 1XXX\},$
	6th case:	$\{F_1 = XXXX X0XX 1XXX, F_2 = XXXX X1XX 1XXX\},$
	7th case:	$\{F_1 = XXXX XX0X 1XXX, F_2 = XXXX XX1X 1XXX\},$
	8th case:	$\{F_1 = XXXX XXX0 1XXX, F_2 = XXXX XXX1 1XXX\},$
	9th case:	$\{F_1 = XXXX XXXX 10XX, F_2 = XXXX XXXX 11XX\},$
25	10th case:	$\{F_1 = XXXX XXXX 1X0X, F_2 = XXXX XXXX 1X1X\},$
	11th case:	$\{F_1 = XXXX XXXX 1XX0, F_2 = XXXX XXXX 1XX1\}.$

In this example, there are 11 potential configurations for the first filter set. Below is a listing that shows the wanted messages accepted by each potential filter set  
 30 configuration:

	1st potential configuration:	$\{F_1 \text{ accepts } (m_1, m_4, m_6), F_2 \text{ accepts } (m_2, m_3, m_5)\},$
	2nd potential configuration:	$\{F_1 \text{ accepts } (m_1, m_2, m_5, m_6), F_2 \text{ accepts } (m_3, m_4)\},$
	3rd potential configuration:	$\{F_1 \text{ accepts } (m_4, m_5), F_2 \text{ accepts } (m_1, m_2, m_3, m_6)\},$
	4th potential configuration:	$\{F_1 \text{ accepts } (m_2, m_3, m_5), F_2 \text{ accepts } (m_1, m_4, m_6)\},$
35	5th potential configuration:	$\{F_1 \text{ accepts } (m_1, m_2, m_3, m_4, m_6), F_2 \text{ accepts } (m_5)\},$
	6th potential configuration:	$\{F_1 \text{ accepts } (m_2, m_3, m_5), F_2 \text{ accepts } (m_1, m_4, m_6)\},$
	7th potential configuration:	$\{F_1 \text{ accepts } (m_1, m_3, m_5, m_6), F_2 \text{ accepts } (m_2, m_4)\},$
	8th potential configuration:	$\{F_1 \text{ accepts } (m_1, m_2, m_4), F_2 \text{ accepts } (m_3, m_5, m_6)\},$
	9th potential configuration:	$\{F_1 \text{ accepts } (m_1, m_2, m_4, m_5, m_6), F_2 \text{ accepts } (m_3)\},$
40	10th potential configuration:	$\{F_1 \text{ accepts } (m_1, m_3, m_4, m_5), F_2 \text{ accepts } (m_2, m_6)\},$
	11th potential configuration:	$\{F_1 \text{ accepts } (m_2, m_3, m_4, m_5, m_6), F_2 \text{ accepts } (m_1)\}.$

Each filter for each potential configuration is then separately optimized, resulting

5 in the following potential configurations of  $F_1$  and  $F_2$  below:

- 1st potential configuration:  $\{F_1 = 0XX1\ 01XX\ 10XX, F_2 = 1XX0\ X0XX\ 1XX0\}$ ,
- 2nd potential configuration:  $\{F_1 = X0XX\ XXXX\ 10XX, F_2 = X1XX\ 0XXX\ 1X00\}$ ,
- 3rd potential configuration:  $\{F_1 = XX0X\ XXXX\ 1000, F_2 = XX1X\ 0XXX\ 1XXX\}$ ,
- 4th potential configuration:  $\{F_1 = 1XX0\ X0XX\ 1XX0, F_2 = 01X1\ 0100\ 10XX\}$ ,
- 10 5th potential configuration:  $\{F_1 = XXXX\ 0XXX\ 1XXX, F_2 = 1000\ 1001\ 1000\}$ ,
- 6th potential configuration:  $\{F_1 = 1XX0\ X0XX\ 1XX0, F_2 = 0XX1\ 01XX\ 10XX\}$ ,
- 7th potential configuration:  $\{F_1 = XXXX\ XX0X\ 1XXX, F_2 = 0000\ 0X10\ 10X0\}$ ,
- 8th potential configuration:  $\{F_1 = XXXX\ 0XX0\ 10XX, F_2 = XXXX\ XXX1\ 1XX0\}$ ,
- 9th potential configuration:  $\{F_1 = XXXX\ XXXX\ 10XX, F_2 = 1110\ 0001\ 1100\}$ ,
- 15 10th potential configuration:  $\{F_1 = XXXX\ XXXX\ 1X0X, F_2 = X01X\ 0XXX\ 1010\}$ ,
- 11th potential configuration:  $\{F_1 = XXXX\ XXXX\ 1XX0, F_2 = 0011\ 0100\ 1001\}$ .

The number of unwanted messages accepted in each optimized case above is:

- 1st optimized potential configuration:  $2^6 + 2^6 - 6$
- 20 2nd optimized potential configuration:  $2^9 + 2^7 - 6$
- 3rd optimized potential configuration:  $2^6 + 2^9 - 6$
- 4th optimized potential configuration:  $2^7 + 2^3 - 6$
- 5th optimized potential configuration:  $2^{10} + 2^0 - 6$
- 6th optimized potential configuration:  $2^7 + 2^6 - 6$
- 25 7th optimized potential configuration:  $2^{10} + 2^2 - 6$
- 8th optimized potential configuration:  $2^8 + 2^9 - 6$
- 9th optimized potential configuration:  $2^{10} + 2^0 - 6$
- 10th optimized potential configuration:  $2^8 + 2^5 - 6$
- 11th optimized potential configuration:  $2^{10} + 2^0 - 6$

The optimized potential configuration for the first set of filters is chosen based on a selection criteria. One preferred selection criteria is to minimize the amount of unwanted messages allowed to pass through the first set of filters. To achieve this desired result, the 1st optimized potential configuration should be selected, i.e.,  $\{F_1 =$   
 35  $0XX1\ 01XX\ 10XX, F_2 = 1XX0\ X0XX\ 1XX0\}$ . A comparison between the filtering capability of the single filter and the dual filter set is:  $(2^{11} - 6) / (2^6 + 2^6 - 6)$ ; a reduction of approximately 16 times less messages.

In addition to the selection criteria, other known information can affect the selection of the filter set to be utilized. For example, it may be known that a particular  
 40 unwanted message has a higher probability of occurring over other unwanted messages. Thus, a filter set configuration should be chosen that will reject this specific unwanted message; even though in theory, the selected configuration potentially allows more unwanted messages to pass through the filter configuration.



For a three filter set configuration, i.e.,  $F = \{F_1, F_2, F_3\}$ ; it is preferable to utilize the optimized two filter configuration, if available — in this example, case 1 would be utilized. However, any of the determined two filter configurations can be utilized with the third filter. Each of the 11 potential two-filter configuration cases determined earlier and shown below can be utilized with the third filter to determine a desired configuration for the three-filter set:

- 1st case:  $\{F_1 = 0XX1\ 01XX\ 10XX, F_2 = 1XX0\ X0XX\ 1XX0\}$ ,
- 2nd case:  $\{F_1 = X0XX\ XXXX\ 10XX, F_2 = X1XX\ 0XXX\ 1X00\}$ ,
- 3rd case:  $\{F_1 = XX0X\ XXXX\ 1000, F_2 = XX1X\ 0XXX\ 1XXX\}$ ,
- 4th case:  $\{F_1 = 1XX0\ X0XX\ 1XX0, F_2 = 01X1\ 0100\ 10XX\}$ ,
- 5th case:  $\{F_1 = XXXX\ 0XXX\ 1XXX, F_2 = 1000\ 1001\ 1000\}$ ,
- 6th case:  $\{F_1 = 1XX0\ X0XX\ 1XX0, F_2 = 0XX1\ 01XX\ 10XX\}$ ,
- 7th case:  $\{F_1 = XXXX\ XX0X\ 1XXX, F_2 = 0000\ 0X10\ 10X0\}$ ,
- 8th case:  $\{F_1 = XXXX\ 0XX0\ 10XX, F_2 = XXXX\ XXX1\ 1XX0\}$ ,
- 9th case:  $\{F_1 = XXXX\ XXXX\ 10XX, F_2 = 1110\ 0001\ 1100\}$ ,
- 10th case:  $\{F_1 = XXXX\ XXXX\ 1X0X, F_2 = X01X\ 0XXX\ 1010\}$ ,
- 11th case:  $\{F_1 = XXXX\ XXXX\ 1XX0, F_2 = 0011\ 0100\ 1001\}$ .

Utilizing  $F_1$  and  $F_2$  of the selected two filter configuration, a third filter,  $F_3$ , is set equal to  $F_1$  wherein  $F_1$ ,  $F_2$ , and  $F_3$  compose a second filter set having  $F_1$  equal to  $F_3$ . A third filter set is also composed wherein its third filter,  $F_3$ , is set equal to the second filter,  $F_2$ ; thus, the third filter set comprises  $F_1$ ,  $F_2$ , and  $F_3$  wherein  $F_2$  and  $F_3$  are equal.

Thus, third filter,  $F_3$ , is associated with each case wherein a second filter set and a third filter set are constructed. The second and third filter sets each comprise three filters,  $F_1$ ,  $F_2$ , and  $F_3$ .  $F_1$  and  $F_3$  of the second filter set are set equal to each other; and  $F_3$  is set equal to  $F_2$  of the third filter set. Beginning with the first case,  $\{F_1 = 0XX1\ 01XX\ 10XX, F_2 = 1XX0\ X0XX\ 1XX0\}$ , the initial configurations of the second filter set are configured by individually setting each undefined component of  $F_1$  to 0 and each corresponding undefined filter component of  $F_3$  to 1, respectively, as follows:

- 1st case, subcase1:  $\{F_1 = 00X1\ 01XX\ 10XX, F_2 = 1XX0\ X0XX\ 1XX0, F_3 = 01X1\ 01XX\ 10XX\}$
- 1st case, subcase2:  $\{F_1 = 0X01\ 01XX\ 10XX, F_2 = 1XX0\ X0XX\ 1XX0, F_3 = 0X11\ 01XX\ 10XX\}$ ,
- 1st case, subcase3:  $\{F_1 = 0XX1\ 010X\ 10XX, F_2 = 1XX0\ X0XX\ 1XX0, F_3 = 0XX1\ 011X\ 10XX\}$ ,
- 1st case, subcase4:  $\{F_1 = 0XX1\ 01X0\ 10XX, F_2 = 1XX0\ X0XX\ 1XX0, F_3 = 0XX1\ 01X1\ 10XX\}$ ,

5 1st case, subcase5:  $\{F_1 = 0XX1\ 01XX\ 100X, F_2 = 1XX0\ X0XX\ 1XX0, F_3 = 0XX1\ 01XX\ 101X\}$ ,  
1st case, subcase6:  $\{F_1 = 0XX1\ 01XX\ 10X0, F_2 = 1XX0\ X0XX\ 1XX0, F_3 = 0XX1\ 01XX\ 10X1\}$ .

10 The same is done for  $F_1$  and  $F_3$  of the third filter set:

1st case, subcase7:

$\{F_1 = 0XX1\ 01XX\ 10XX, F_2 = 10X0\ X0XX\ 1XX0, F_3 = 11X0\ X0XX\ 1XX0\}$ ,

1st case, subcase8:

15  $\{F_1 = 0XX1\ 01XX\ 10XX, F_2 = 1X00\ X0XX\ 1XX0, F_3 = 1X10\ X0XX\ 1XX0\}$ ,

1st case, subcase9:

$\{F_1 = 0XX1\ 01XX\ 10XX, F_2 = 1XX0\ 00XX\ 1XX0, F_3 = 1XX0\ 10XX\ 1XX0\}$ ,

1st case, subcase10:

$\{F_1 = 0XX1\ 01XX\ 10XX, F_2 = 1XX0\ X00X\ 1XX0, F_3 = 1XX0\ X01X\ 1XX0\}$ ,

20 1st case, subcase11:

$\{F_1 = 0XX1\ 01XX\ 10XX, F_2 = 1XX0\ X0X0\ 1XX0, F_3 = 1XX0\ X0X1\ 1XX0\}$ ,

1st case, subcase12:

$\{F_1 = 0XX1\ 01XX\ 10XX, F_2 = 1XX0\ X0XX\ 10X0, F_3 = 1XX0\ X0XX\ 11X0\}$ ,

1st case, subcase13:

25  $\{F_1 = 0XX1\ 01XX\ 10XX, F_2 = 1XX0\ X0XX\ 1X00, F_3 = 1XX0\ X0XX\ 1X10\}$ .

The process continues for each subsequent case until all 11 potential filter configurations have been done. A three-filter set is then selected from all the cases and subcases determined in accordance with the selection criteria.

30 It is to be understood that the present invention is applicable for an P-filter set ( $P > 3$ ); i.e.,  $F = \{F_1, F_2, \dots, F_P\}$  wherein optimization of each potential filter set configuration is recursively determined via the steps shown above and the selected P-filter setting is chosen based on any constraints of the selection criteria.

35 While specific embodiments and exemplifications of the present invention have been illustrated and described, numerous modifications are possible without departing from the scope or spirit of the invention.